



# Reliability and Validity of Kubios HRV Smart Phone Application as Measures of Heart Rate Variability

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## ABSTRACT

**Introduction:** Heart rate variability (HRV) analysis has given a non-invasive way for assessing cardiac autonomic control. Reduced HRV is an independent indicator of poor prognosis in both heart disease patients and the general population.

**Aim/Objective:** To establish reliability and validity for Kubios HRV smart phone application.

**Materials and methods:** Fifty (n =50) office workers volunteered for the study, with 10 females and 40 males ranging in age from 30 to 50 years (Mean age =38.4±5.6). To evaluate Intra and Inter-rater reliability and validity the of HRV parameter, R-R intervals comparing simultaneous recording from ECG and Kubios HRV app, at different three times (day1, day2 & day3) one day apart and by two different trained examiners in the same participants. Each participants rested in supine for 10 minutes prior to the assessment and was instructed to remain relaxed, breathe properly, and refrain from talking and sleeping during the measurement. The RR intervals (R-R) were recorded during a 5 min period in supine position using ECG and polar H10 monitor with Kubios HRV smartphone application.

**Results:** Kubios HRV smart phone application shows excellent reliability, Intra-rater ( $\alpha = 0.868$ ) and Inter-rater ( $\alpha = 0.890$ ) and Validity ( $r = 0.94$ ) with R-R intervals calculated from ECG.

**Conclusion:** The Kubios HRV smart phone application provides an accurate and reliable alternative to the ECG for acquiring inter-beat interval time series data. The Kubios HRV app gives an R-R interval that can be used for short term HRV analysis in office workers from steady resting conditions, supporting the selection of this approach of evaluation in research and clinical practise.

**Key Words:** Variability, HRV, Kubios HRV app, Office workers, Reliability and Validity, Kubios HRV software.

## INTRODUCTION

Heart rate variability (HRV) is the variation in the time intervals between heartbeats. <sup>1</sup> HRV measures neuro-cardiac function and is produced by heart-brain connections and dynamic non-linear autonomic nervous system (ANS) activities. HRV is an emergent characteristic of interconnected regulatory systems that work on various time scales to aid in our adaptation to environmental and psychological stresses. HRV regulates autonomic balance, blood pressure (BP), gas exchange, stomach, heart, and vascular tone (the diameter of blood vessels that govern BP), as well as maybe face muscles. <sup>2</sup>

The clinical significance of heart rate variability was first recognised in 1965, when Hon and Lee discovered that foetal discomfort was preceded by changes in inter-beat intervals before a noticeable change in heart rate occurred. <sup>3</sup> Heart rate

variability analysis is a valuable clinical tool for characterising cardiac autonomic state and has developed into a tool for anticipating the future. The HRV has a wide range of uses, from sports and preventative medicine to early detection of cardiovascular disease (CVD) and risk assessment for a variety of diseases. Reduced HRV is an independent indicator of poor prognosis in both heart disease patients and the general population. <sup>4</sup>

A high level of HRV is related with good health, self-regulation, adaptation, and resilience. Higher levels of resting vagally-mediated HRV are associated with prefrontal cortical performance on executive activities such as attention and affective processing. <sup>1</sup>

Heart rate variability can be measured using a battery of basic bedside reflex tests or more complex computer-based techniques that reflect RR interval changes. HRV can be

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evaluated using electrocardiograms (ECGs) in a variety of ways, including time- and frequency-domain analysis, as well as nonlinear techniques. Long-term (at least 18 hours), Holter ECG recordings or short-term (generally 5 minutes) ECG recordings collected under controlled standardised settings are typically used in the analysis to avoid any effect from external stimuli that may affect autonomic nerve tone. A variety of methods can be used to assess variations in heart rate. It encompasses time domain, frequency domain, and nonlinear measuring methods. HRV time-domain indices quantify the amount of variability in inter-beat interval (IBI) data, which is the time interval between successive heartbeats. Selected time-domain measures of HRV are Standard deviation of all NN intervals (SDNN), The root mean square of successive differences between normal heartbeats (RMSSD), The standard deviation of the IBIs for all sinus beats (SDRR), The standard deviation of the average normal-to-normal (NN) intervals for each of the 5 min segments during a 24 h recording (SDANN), The SDNNI is the mean of the standard deviations of all the NN intervals for each 5 min segment of a 24-h HRV recording, The number of adjacent NN intervals that differ from each other by more than 50 ms (NN50) requires a 2 min period, The percentage of adjacent NN intervals that differ from each other by more than 50 ms (pNN50) also requires a 2-min period. The distribution of absolute or relative power into four frequency bands is evaluated using frequency-domain measurements. Frequency-domain measurements are ultra-low-frequency (ULF), very-low-frequency (VLF), low-frequency (LF), and high-frequency (HF) bands and LF/HF Ratio.<sup>5</sup>

The electrocardiogram (ECG) is the gold standard measure for quantifying RR intervals and assessing HRV.<sup>6</sup> However, for data collection, storage, analysis, and export, it has been usual practise to employ mobile systems (e.g., apps, wearable devices) and chest straps, which offer improved practicability in terms of cost, convenience of use, portability, and interpretation.<sup>7,8,9</sup> However, in order to verify the reliability and validity of the RR interval data for subsequently HRV interpretation, these applications and sensor devices must be evaluated in varied populations.

Purpose of the study was to establish validity and reliability for Kubios HRV smart phone application. Gold standard measurement of HRV is ECG monitoring which is not practically possible due to costing and feasibility as well as to obtain an almost immediate test result hence there is need to use alternative method which provide robust and accurate measurement. The R-R intervals recorded from the 12 lead ECG and the Polar H10 chest strap monitor were compared in this study using the Kubios HRV smart phone application. New approaches to HRV analysis are required to make HRV recording an accurate tool for field measurements. To date, there are no data in terms of the validity or reliability of Kubios HRV smart phone application.

## MATERIALS AND METHOD

The cross-sectional study was carried out at RMV Impex diamond institute in Surat, Gujarat, India. The purpose of the study was explained to all participants and informed consent was acquired. This study is part of a larger research initiative, and the study techniques were authorised by the Institutional Ethical Committee.

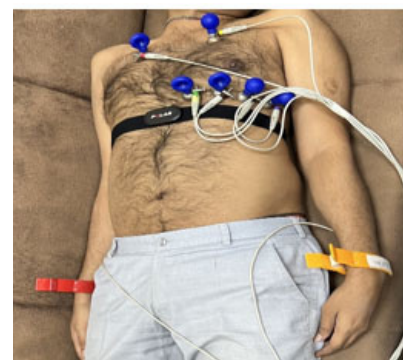
### Participants

50 (n=50) Office workers of both gender (male=40, female=10), age between 30-50 years were included in the study. Participants who had any cardiac-respiratory disease, endocrinal disease and implanted pacemaker were excluded from the study.

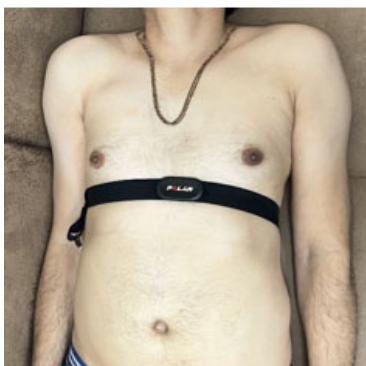
### Heart Rate Variability Measurement

The R-R interval was measured using a 12-lead ECG (BPL CARDIART 6208 VIEW) and a Polar H10 monitor (an elastic chest belt) with the Kubios HRV smart application version 1.2.7(24) (iPhone 13 pro max). Polar H10 monitor is considered as the gold standard for measuring RR intervals.<sup>10</sup> All recordings were performed in a quiet, bright room, with stable, controlled temperature in morning between 8 am to 12 pm. Each Participants were rested in supine for 10 minutes before the measurement and were instructed to remain relaxed, breathe normally, and refrain to talk and sleep during the measurement.

Following a 10-minute rest, ECG limb and chest leads were connected to conventional recording locations. Physician obtained a 5-minute ECG recording. Simultaneously, a moistened Polar H10 chest strap was applied to the participant's chest at the level of the xiphisternum, and the Kubios HRV smart phone application was connected to the iPhone via Bluetooth for recording. Relaxation period before actual measurement was 30 sec and the entire recording time was 5 minutes for App. For validity measurement, R-R intervals were simultaneously obtained via electrocardiogram and the Polar H10 through Kubios HRV smart phone application.



**Image 1:** ECG electrodes and PolarHR10



**Image2.** PolarHR10

Kubios HRV app works with only Bluetooth HR sensors, which measure and transmit beat-to-beat RR intervals to phone. In general, a chest strap HR sensor that detects the electrical activity of the heart (i.e. electrocardiogram or ECG) and extracts RR interval values is recommended for accurate HRV analysis.

#### Recommended HR sensors:

1. Polar H10 is a chest strap HR monitor that monitors electrical activity in the heart and offers RR interval measurements that are consistent and accurate
2. Polar Verity Sense, other compatible HR sensors are Polar H7 (chest strap), CorSense by Elite HRV (optical sensor), Suunto Smart Belt (chest strap) and Wahoo TICKR (chest strap). Apple watch and ANT+ sensors are not supported.

For reliability assessments, the testing sessions were separated by at least one day for each participants. Intra rater reliability was determined by taking the R-R interval from the Kubios HRV application on two separate days (baseline and after three days) by the same examiner at the same time and using the same standardised condition on the same individuals. Inter rater reliability was determined by taking the R-R interval from the Kubios HRV application by two different examiners on two different days (one day apart) at the same time and under the same standardised conditions on the same subjects.

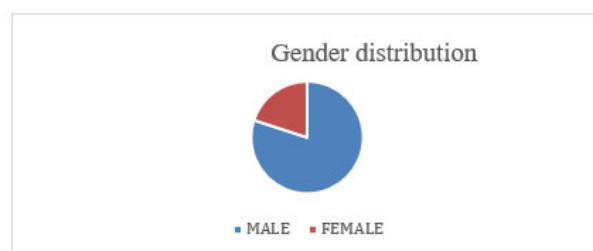
Artefacts, both technical and physiological, observed even in healthy persons during rest conditions have a considerable influence on HRV values, particularly those estimated based on short-term recordings. However, there is no standardised, universal approach for artefact correction.<sup>11</sup> Artefacts were corrected in this study by adjusting the chest strap.

## RESULTS

The data was analysed using SPSS version 28. Pearson's correlation coefficient ( $r$ ) was utilised to determine the validity of the HRV parameter. Cronbach's alpha was used to assess the intra and inter-rater reliability of HRV parameters.

**Table 1: Demographic details**

| Variables                   | Mean (SD) |
|-----------------------------|-----------|
| 1. Age (years)              | 38.4±5.6  |
| 2. BMI (Kg/m <sup>2</sup> ) | 23.8±3.7  |
| 3. RHR (bpm)                | 75.8±9.8  |
| 4. Silting hours (weekly)   | 68.1±4.4  |



**Graph 1:** Gender distribution.

**Table 2: VALIDITY**

| Correlation coefficient ( $r$ ) | Interpretation |
|---------------------------------|----------------|
| 0.94                            | Excellent      |

**Table 3: RELIABILITY**

| Reliability | Cronbach's alpha ( $\alpha$ ) | Interpretation |
|-------------|-------------------------------|----------------|
| Intra-rater | 0.868                         | Excellent      |
| Inter-rater | 0.890                         | Excellent      |

The results demonstrate that the Kubios HRV app has excellent validity ( $r = 0.94$ ) and excellent reliability, intra ( $\alpha=0.868$ ) and inter ( $\alpha=0.890$ ).

## DISCUSSION

The findings of this study indicate that the Kubios HRV application is valid and reliable for measuring HRV. Validity and reliability analyses of polar H10 and Kubios software has been established. However, to the best of our knowledge, the current study is the first to investigate the validity and reliability of a Kubios HRV smart phone application. Kubios HRV app features includes, it is available for Android and iOS system. It is Compatible with Polar H10 and Verity Sense (Polar SDK) and other Bluetooth sensors supporting R-R interval data. There are two modes of operation: 1.Readiness measurement mode for athletes and indi-

viduals who want to monitor changes in their daily readiness status 2. Custom measurement mode for researchers, health and wellbeing professionals, and sport scientists for performing various types of HRV recordings (R-R/IBI, ECG or PPG data available depending on the sensor), this mode required a Kubios HRV software license. If we do not have this version measurement runs in demo mode, data is not stored. Advancements in computing technology have eased the telemetric detection, recording, and analysis of inter-beat interval data, therefore Kubios HRV App can be used in different settings such as sport, exercise and fitness.

## CONCLUSION

HRV monitoring and measurement via ECG is difficult and impractical to use in mass testing as well as it is not cost effective. Kubios HRV application is easy to use and free access for HRV measurement which is reflecting all the HRV parameters includes time domain and frequency domain parameters with immediate test results.

## LIMITATIONS

It should also be highlighted that, despite the investigator's best efforts to simultaneously push "start" on the ECG monitor and the Kubios HRV programme, the synchronisation of start times may not have been accurate. Furthermore, time gaps inside the Kubios HRV app could have occurred when transitioning from the relaxation to recording period. Variables known to affect HRV such as lifestyle factors (e.g., diet, physical activity, environment, sleep, respiration and hormonal etc.) were not controlled. Lifestyle factors known to affect HRV (e.g., nutrition, physical activity, environment, sleep, respiration, hormonal, and so on) were not controlled. However, the focus of the study was not to look into the relationship between these variables and HRV. Corrections to artefacts were not performed.

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This study received no external funding.

## Conflicts of Interest

The authors declares no conflict of interest.

## Abbreviations

RR – R – R INTERVAL

IBI- INTER BEAT INTERVAL

ECG-ELECTROCARDIOGRAM

PPG-PHOTO-PLETHYSMOGRAM

## Author's contribution

Vaishali Gabani: Conceptualization, methodology, Writing –review & editing, writing-original draft preparation, funding. Saravanan M; Conceptualization, methodology, data analysis & interpretation.

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